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Late Devonian (Frasnian–Famennian) palynomorphs from the Padeha and Bahram Formations of Shahzadeh Mohammad section, northwest of Kerman, Iran

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ABSTRACT. A diverse and well-preserved microphytoplankton assemblage is reported from a measured section of Frasnian–Famennian (Upper Devonian) Padeha and Bahram Formations in Shahzadeh Mohammad area, northwestern Kerman, southeast Iran. The palynoflora assemblage contains 17 genera and 23 species of acritarchs, chitinozoa, scolecodont and rich miospore taxa. 57 species (25 genera) of miospores were identified and 5 assemblage biozones were defined from the Shahzadeh Mohammad section. The miospore composition is similar to neighboring localities in Southern and Northern Iran, but it shows significant similarities with palynoflora from more distant localities, e.g. Saudi Arabia, Western Australia or Algeria. This implies a close relationship between the Iranian platform and other areas of the Northern Gondwana and southern Laurentia Domain during the late Devonian. The investigated section was deposited in a shallow marine environment with tropical conditions during the Frasnian-Famennian period.

KEYWORDS: Palynoflora, Devonian, palynostratigraphy, paleogeography, Iran, Padeha, Bahram

INTRODUCTION

Although the Paleozoic flora of Iran has been studied in considerable detail, a number of controversial results have been published in the last few decades. Extensive palynologic studies have shown that specific plant climate zones existed in the Devonian period in Iran. The first palynological study that clarified the Devonian paleogeography of Iran was conducted by Ghavidel-Syooki (1988) on the Faraghun Formation. This palynological study on the Paleozoic sediments of Alborz, Central Iranian Domain and Zagros fold belt (Fig. 1) clarified the paleogeographical position of various Iranian sedimentary basins in different Paleozoic periods. According to Went et al. (2002), the middle Givetian–early Famennian age has been assigned to the Bahram Formation. Also, in this area, middle Frasnian – early Famennian age was assigned to the Bahram Formation based on conodont investigations (Gholamalian et al., 2014; Zamani et al., 2021). In the same section, based on the study of the acritarch, the late Devonian (Frasnian-Famennian) age was proposed by Ghavidel-Syooki et al. (2011), while the middle-late Devonian age was reported based on the study of conodonts by Zamani et al. (2021).

In the present study, a diverse and well-preserved late Devonian palynoflora has been reported from the Padeha Formation and the

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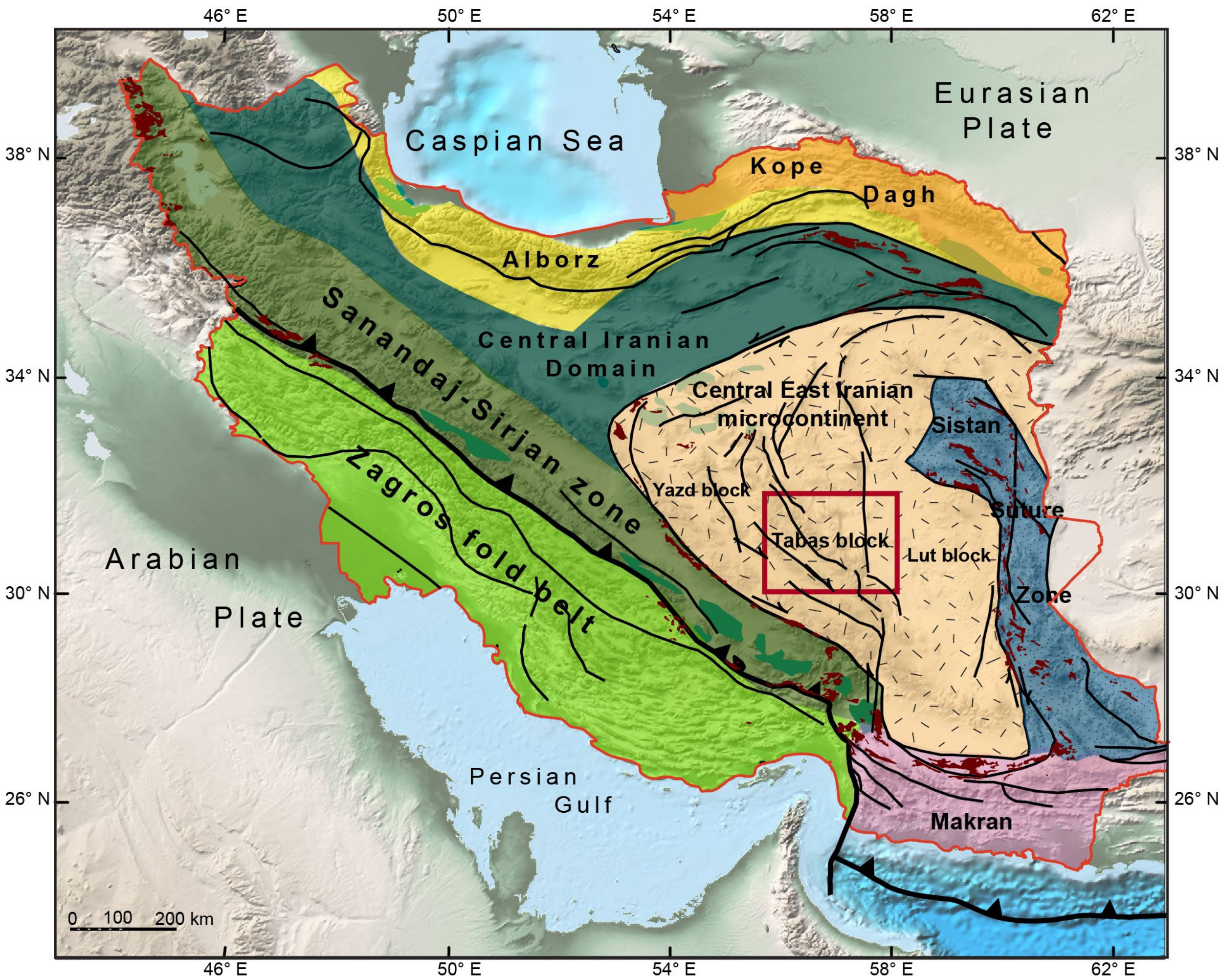

Figure 1. Present-day map of Iran with the main tectonic units indicated in different colors

basement of the Bahram Formation and a new palynostratigraphical zonation is established for the late Devonian that may be used on a regional scale for Central Iran. Comparison with other late Devonian assemblages (e.g. Western Australia or North Africa) allows to understand and correlate the miospore composition and the global distribution during this time interval. In addition, new data on the depositional paleoenvironmental setting of the investigated units are presented herein.

GEOLOGICAL SETTING

The Shahzadeh Mohammad section is located in the central part of the Central East Iranian Microcontinent (Takin, 1972; Stocklin, 1974; Fig. 1) which consists of three tectonically highly complicated main structural units: the Lut, Tabas, and Yazd Blocks (e.g. Zand-Moghadam et al., 2013; Fig. 1). During the Paleozoic, the Tabas Block was part of the northern margin of Gondwana (Fig. 2) and during Devonian time was located south of the paleo-equator (Wendt et al., 2002). This area was situated on the continental shelf of the southern part of Paleo-Tethys (Fig. 2). The Paleozoic sequences are widely exposed in the Tabas and Kerman regions, especially the Devonian strata are well exposed in the Shahzadeh Mohammad area, which is located between Shahzadeh Mohammad and Grek villages, ~80 km northwest of Kerman city (Fig. 3). In Kerman, these deposits are limited to the northern parts of the region and are introduced and studied as Padeha and Bahram Formations. The thickness of the Padeha Formation in this section is 212.5 m; it is mainly composed of sandstone and shale with an interlayer of calcareous dolomite. The lower boundary of this formation with the underlying Lalun Formation (Early Cambrian) is erosional, with basal conglomerate, and the upper boundary with the Bahram Formation is gradational. Also, a thick layer of white quartzite presents at the base of the Bahram Formation. The

Figure 2. Paleogeographic map of the world during the late Devonian (after Serobyan et al., 2021). CEIM = Central East Iranian Microcontinent

thickness of the Bahram Formation is 371.5 m in this section; and it consists of gray-yellow limestone containing fossils of brachiopods, corals and crinoids. The upper boundary of the Bahram Formation is an erosive disconformity with the Jamal Formation (Fig. 5).

MATERIALS AND METHODS

A total of 68 samples were taken to obtain palynomorphs for the palynostraitgraphic study of Padeha and Bahram Formations in the Shahzadeh Mohammad area of Kerman. Depth was 20–50 cm below the ground to avoid exposed and weathered rocks (Wood, 1996). Standard palynological techniques were used to process the samples. After transferring the samples to the paleontology laboratory of the Exploration Group of the National Iranian Oil Company (ED-NIOC) and a mild surface washing, the samples were crushed and ~60 g separated and chemically treated in 10% cold HCl for about 24 h, followed by 40% HF for 30 h and 10% hot (90°C) HCl for 20 min. After this process, the samples were rinsed in water and sieved through 15 µm and 35 µm nylon mesh sieves for acritarchs and miospore taxa, respectively. Finally, we used zinc bromide solution with a specific gravity of >2 gr/cm^3 to separate organic residues from inorganic materials and nitric acid to lighten palynomorphs. Distilled water was employed to neutralize each acid at the preparation stage. The resulting organic residue was mounted in glycerin jelly and sealed with paraffin wax in the last stage. A permanent slide of each sample was prepared, numbered and studied according to the National Iranian Oil Company rules. A Zeiss microscope was used to study the palynomorphs, and a Canon power shot was used for photography. The palynomorphs and organic debris range in color from yellow to orange-brown, which indicates a good thermal maturity for the organic materials of Upper Devonian strata in this part of the Central Iran zones. Routine oxidation of the residues during sample preparation prevented any detailed palynofacies investigations from being undertaken. The study of the mentioned slides indicates relatively diverse palynoflora with good preservation in the Padeha and Bahram formations in the measured section. The biozonation of the studied Devonian section was undertaken based on the 'First Appearance Datum' (FAD) and the 'Last Occurrence' (LO) of stratigraphically significant palynomorph and microfossil species. The base of each assemblage biozone is defined by the first appearance of two or more diagnostic species and its top being marked by the base of the succeeding assemblage zone (Fig. 5).

BIOSTRATIGRAPHY

The studied strata in Padeha and Bahram formations contain a large amount of common palynomorphs. A total of 80 palynomorph species were described in these formations, including 23 acritarch species of 17 genera (Ghavidel-Syooki et al., 2011) and 57 miospore species of 25 genera (Appendix 1). Five informal miospore assemblage zones were recognized throughout the Upper Frasnian strata

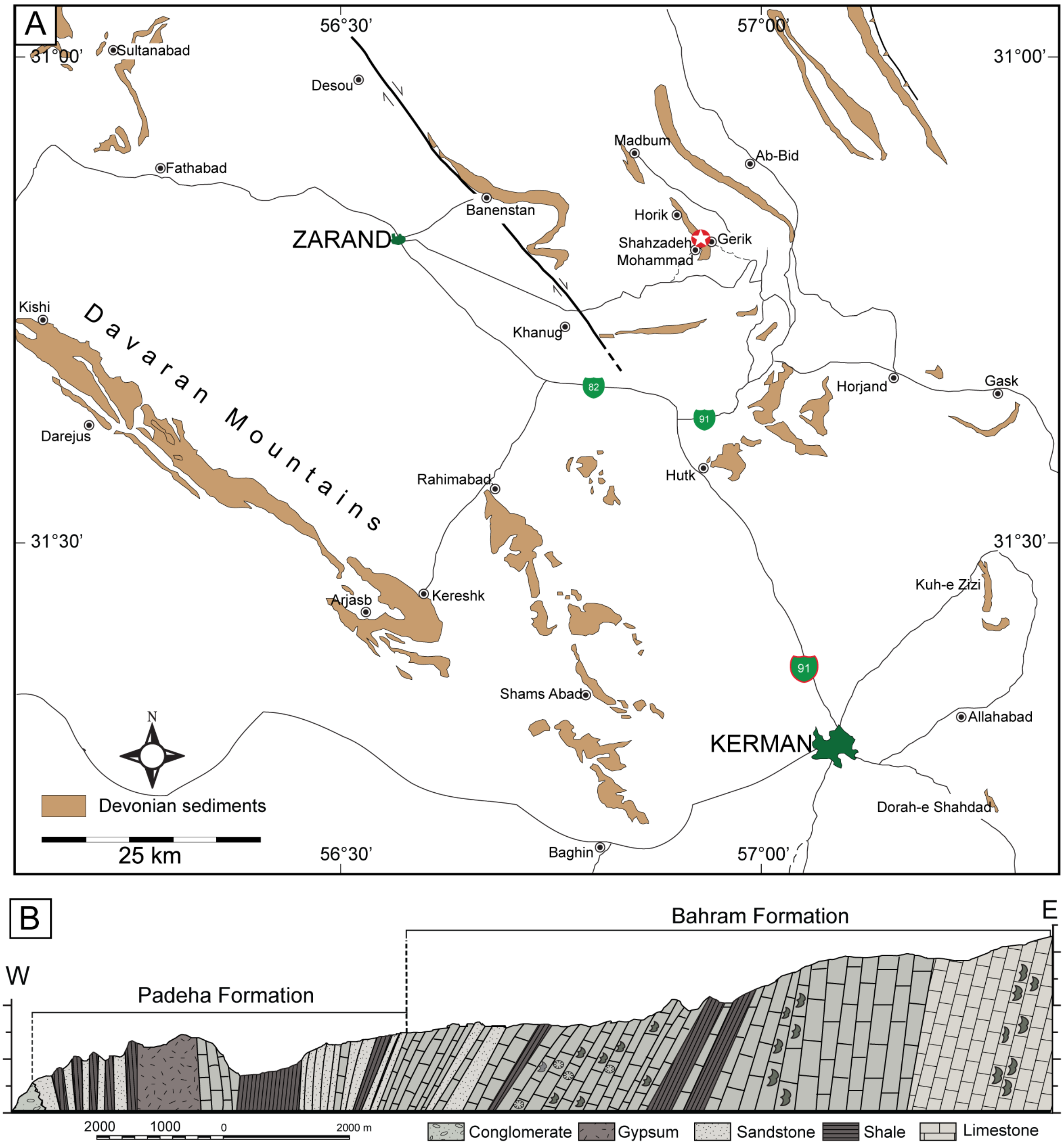

Figure 3. **A**. Distribution of Devonian sequences around the Kerman area (after Wendt et al., 2002); **B**. Cross section of Shahzadeh Mohammad area, NW Kerman

in the study area based on the selected species with known stratigraphic significance (Fig. 5). Selected taxa are illustrated in Plates 1–4.

MIOSPORE BIOZONE I

This biozone is an Interval zone that occurs in the lowermost part of the Padeha Formation and extends through a thickness of 40 m (Fig. 5), composed mainly of alternations of shale and limestone with a few dolomite stringers. This zone is characterized by the first occurrence of miospore taxa including *Cyclogranisporites isostictus*, *Dibolisporites turriculatus*, *Geminospora lemurata*, *Samarisporites triangulatus* and *Samarisporites* sp. The upper boundary is characterized by the first observed occurrence of *Apiculiretusispora fructicosa*, *A. plicata*, *Calamospora pannucea*, *Leiotriletes* sp., *Punctatisporites* sp., *Retusotriletes distinctus*, *R. pychovi*, *R. rotundus* and *Verruciretusispora pallida*. All of these species continue into the succeeding assemblage zone (Fig. 5). Based on the presence of *Cyclogranisporites isostictus*, *Dibolisporites turriculatus*, the early Frasnian age has been proposed to this part of the Padeha Formation (Fig. 3).

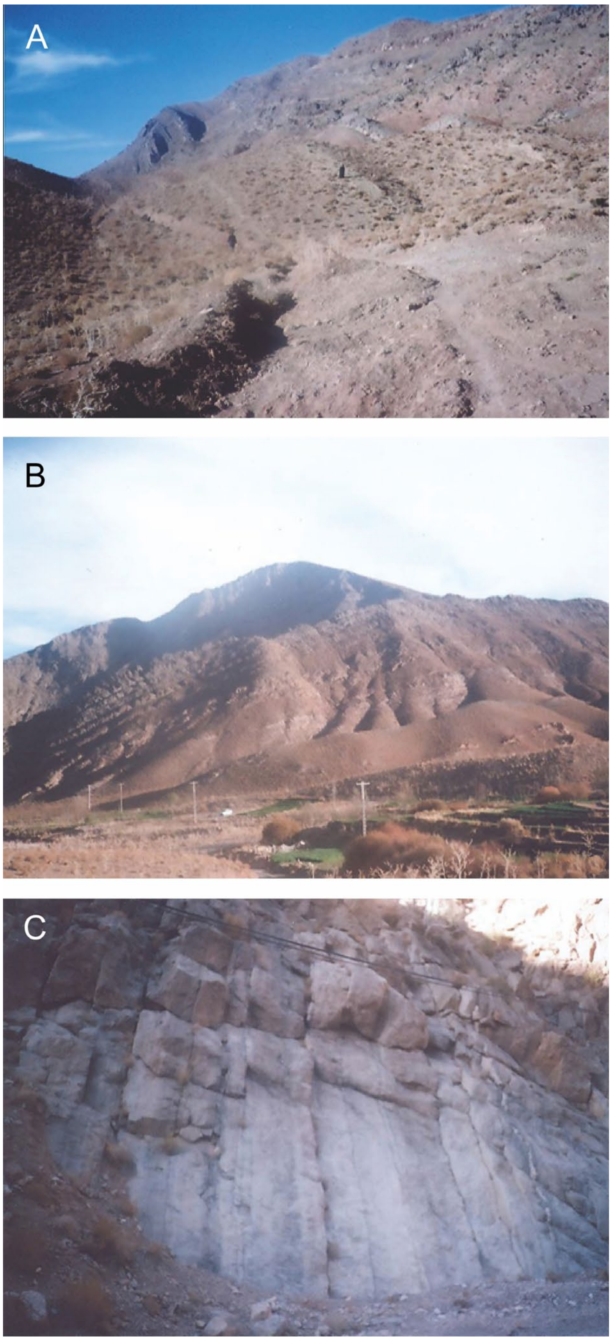

Figure 4. **A**. Field photo of Lalun, Padeha and Bahram formations in Shahzadeh Mohammad area, north of Kerman; **B**. Studied section of Padeha and Bahram formations in Shahzadeh Mohammad area, north of Kerman; **C**. Bedded limestone of Bahram Formation

In addition to the miospore species, some acritarch and prasinophyte species (Fig. 5) are also presented here including *Gorgonisphaeridium abstrusum*, *G. condensum*, *Lophosphaeridium deminutum*, *Leiosphaeridia* sp., *Maranhites perpelexus*, *Navifusa exillis* and *Papulogobata annulata*. Based on the existence of the above-mentioned acritarch species, the early Frasnian age is suggested for this biozone (Ghavidel-Syooki et al., 2011) (see Fig. 5).

MIOSPORE ASSEMBLAGE II

This biozone is an assemblage zone that is also present in the Padeha Formation and in the base of the Bahram Formation, and includes a 317.5 m thick sediment series consisting mainly of sandstone, limestone, fossiliferous limestone and shales with interlayers of limestone (Fig. 4). The lower boundary of this biozone is recognized by the first occurrence of the following miospore taxa: *Apiculiretusispora fructicosa*, *A. plicata*, *Calamospora pannucea*, *Leiotriletes* sp., *Punctatisporites* sp., *Retusotriletes distinctus*, *R. pychovi*, *R. rotundus* and *Verruciretusispora pallida*, while the upper boundary is recognized by the first occurrence of *Ancyrospora ampula*, *Geminospora punctata*, *Grandispora echinata*, *G. famenensis*, *Grandispora* sp. A, *Lophozonotriletes somphus*, *Verrucosisporites confertus* and *V. premnus*. All of these species are present in the succeeding assemblage zone (Fig. 5). Miospore species of this association are assigned to the late Devonian (late Frasnian–early Famennian) age. It should be emphasized that the boundary between Frasnian and Famennian is gradual. Based on recorded miospore taxa, a late Frasnian–early Famennian age is proposed for this biozone (Fig. 3).

Also, five acritarch species are present in this biozone as follows: *Chomotriletes vedugensis*, *Dictyotidium prolatum*, *Gorgonisphaeridium* sp., *Lophosphaeridium deminutum* and *Stellinium micropolygonale*. Based on the previous *Chomotriletes vedugensis* and other acritarch species, this biozone is assigned Frasnian–early Famennian age by (Ghavidel-Syooki et al., 2011) (see Fig. 5).

Additionally, foraminifera and other microfossils such as *Tentaculites* sp. (Ichno fossil), *Archaesphaera* sp. (foraminifera), *Aujgalia* sp. and *Kamacna* sp. (Algae ?), *Nancicella* sp. (Charophyt algae), *Girvanella ducii* (Cyanobacteria) are also present in this part of the section. Based on the wide stratigraphical distribution of these taxa, this part may be assigned to the early Famennian age (Tayefe Khabbazy, 2000) (see Fig. 5).

MIOSPORE ASSEMBLAGE ZONE III

This biozone is an assemblage zone that occurs in the Bahram Formation and extends through a thickness of 60 m consisting of

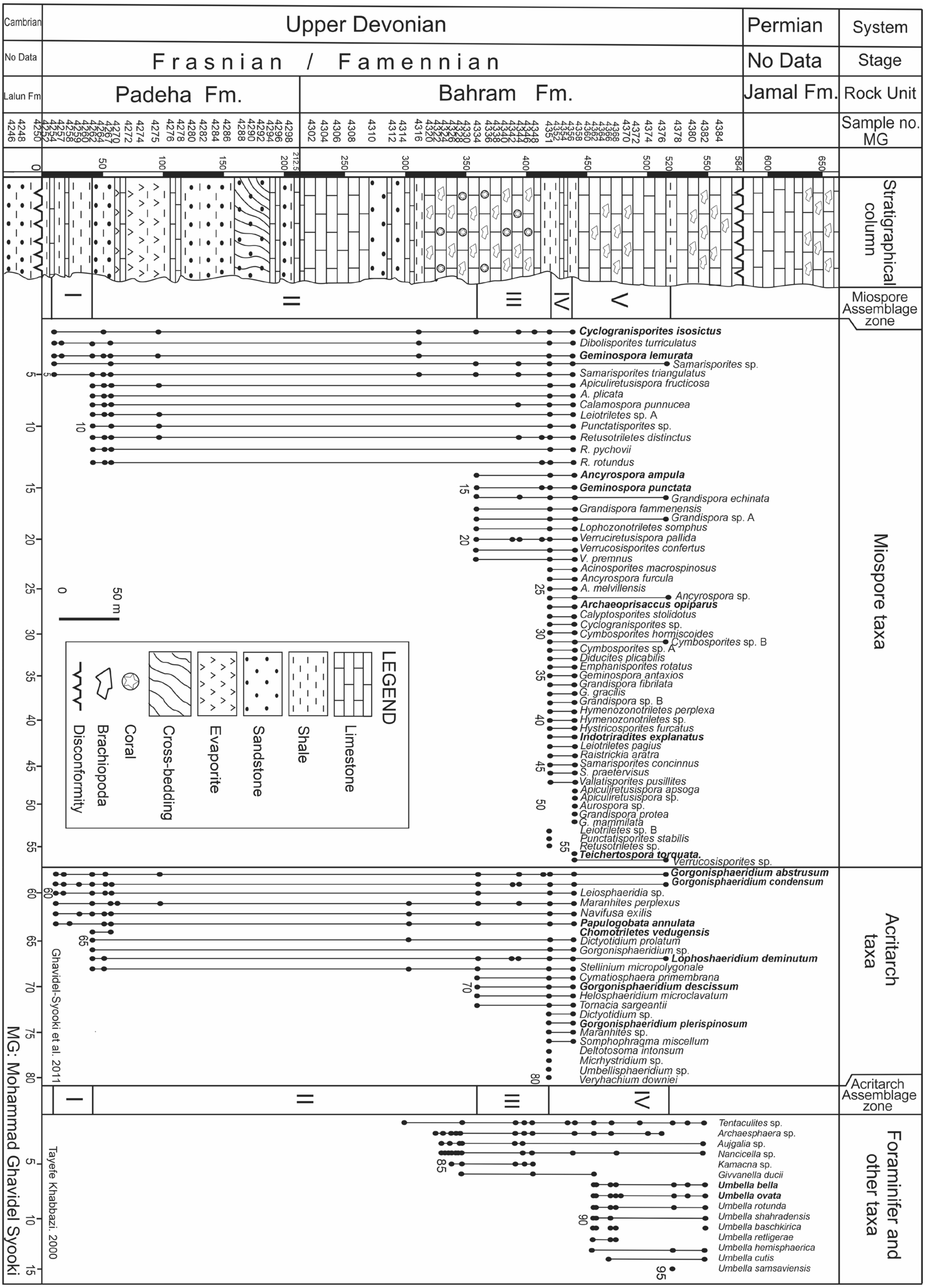

Figure 5. Stratigraphical distribution of miospores in Padeha and Bahram formations in Shahzadeh Mohammad area, NW Kerman

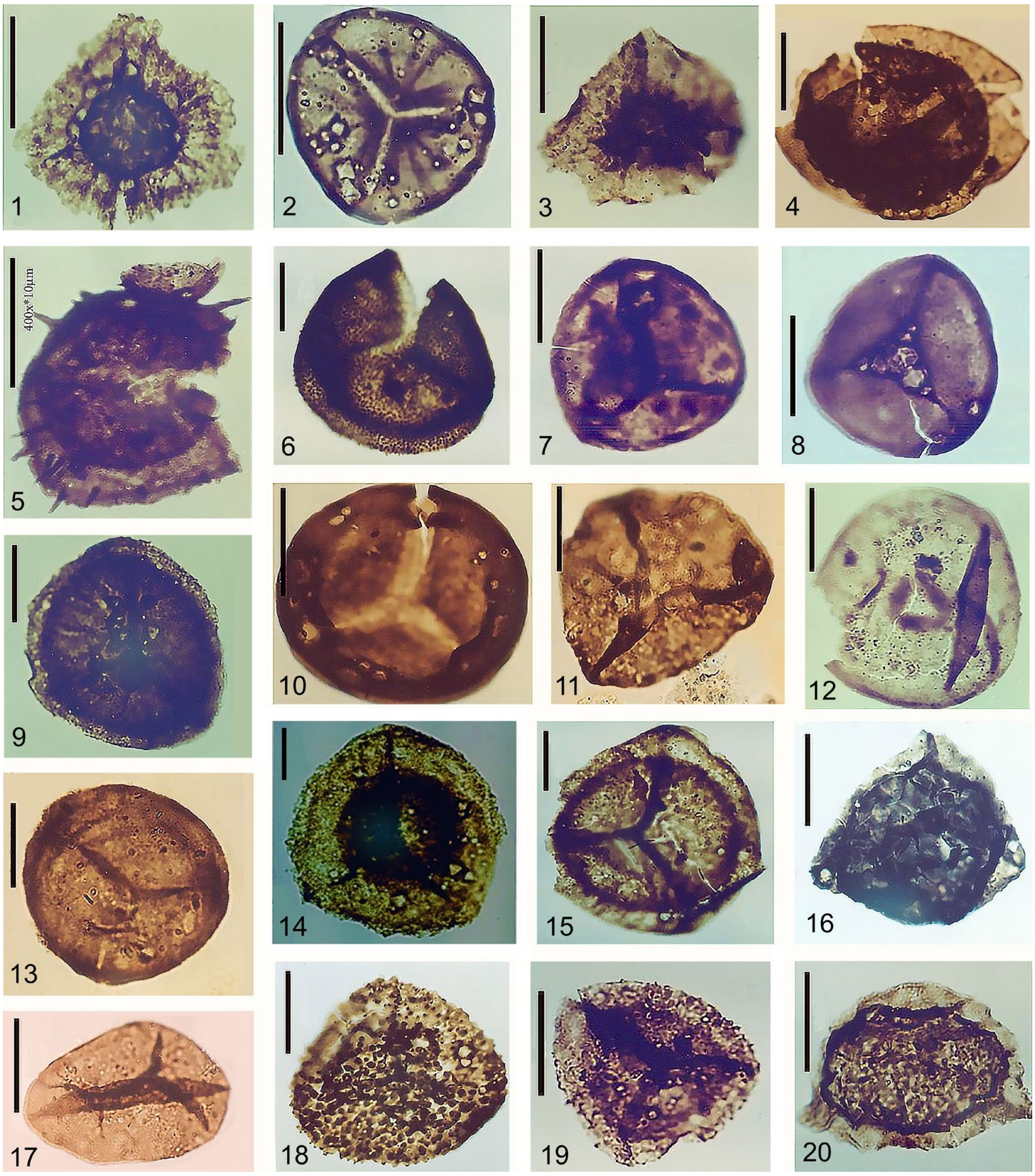

Plate 1. **1**. *Vallatisporites pusillites* (Kedo) Dobly and Neves, 1970 (Sample No. B-4351); **2**. *Emphanisporites rotatus* McGregor, 1961 (Sample No. B-4351); **3**. *Hymenozonotriletes* sp. (Sample No. B-4351); **4**. *Hymenozonotriletes perplexa* Owens, 1971 (Sample No. B-4351); **5**. *Acinosporites macrospinosus* Richardson, 1965 (Sample No. B-4351); **6**. *Apiculiretusispora apsoga* Chibrikova, 1959 (Sample No. B-4355); **7**. *Leiotriletes* sp. A (Sample No. P-4262); **8**. *Cyclogranisporites* sp. (Sample No. P-4351); **9**. *Samarisporites praetervisus* (Naumova) Allen, 1965 (Sample No. B-4351); **10**. *Retusotriletes distinctus* Richardson, 1965 (Sample No. P-4267); **11**. *Apiculiretusispora* sp. (Sample No. B-4355); **12**. *Calamospora pannucea* Richardson, 1965 (Sample No. P-4262); **13**. *Geminospora punctata* Owens, 1971 (Sample No. B-4334); **14**. *Grandispora* sp. A (Sample No. B-4344); **15**. *Diducites plicabilis* (Kedo) Van Veen, 1981 (Sample No. 4355); **16**. *Samarisporites triangulatus* Allen, 1965 (Sample No. B-4316); **17**. *Leiotriletes* sp. B (Sample No. B-4351); **18**. *Grandispora famenensis* (Naumova) Streel in Becker, 1974 (Sample No. 4351); **19**. *Grandispora fibrilata* Balme, 1988 (Sample No. B-4351); **20**. *Indotriradites explanatus* (Luber) Playford, 1991 (Sample No. B-4351). Scale bars = 20 µm

fossiliferous limestone and shales (Fig. 4). Its lower contact is characterized by the first occurrence of miospore taxa including *Ancyrospora ampula*, *Geminospora punctata*, *Grandispora echinata*, *G. famenensis*, *Grandispora* sp. A, *Lophozonotriletes somphus*, *Verrucosisporites confertus* and *V. premnus* while the upper contact is distinguished by the first occurrence of *Ancyrospora furcula*, *A. melvillensis*, *Archaeoprisaccus opiparus*, *Cymbosporites bormiscoides*, *Emphanisporites rotates*, *Grandispora gracilis*, *Hystricosporites furcatus*, *Indotriradites explanatus*, *Samarisporites concinnus* and *Vallatisporites pusillites.* All of these species are present in the succeeding assemblage zone (Fig. 5). Based on the presence of *Archaeoprisaccus opiparus*, *Grandispora gracillis* and *Indotriradiates explanatus*,

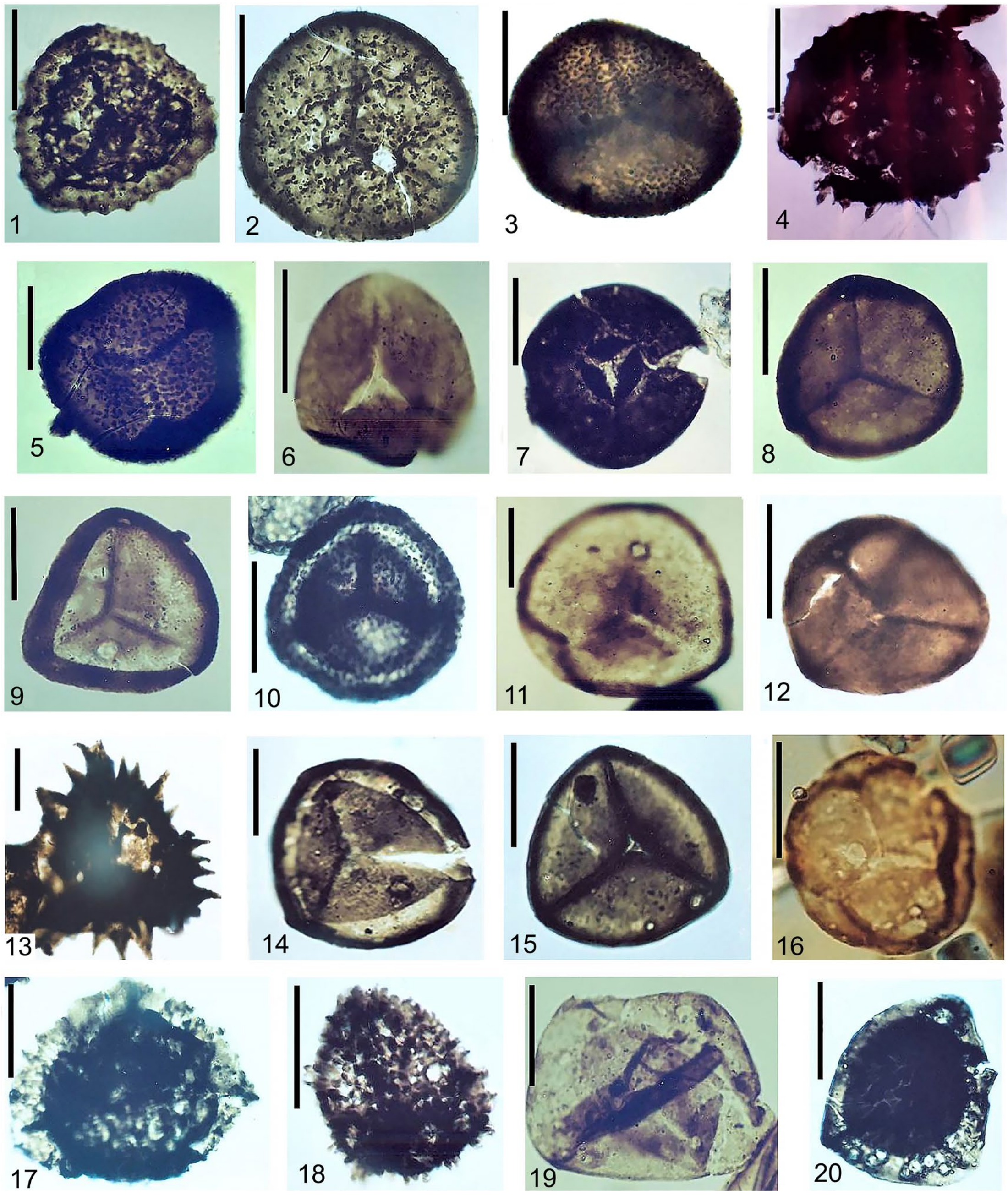

Plate 2. **1**. *Grandispora gracilis* (Kedo) Streel, in Becker et al. 1974 (Sample No. B-4355); **2**. *Dibolisporites turriculatus* Balme, 1988 (Sample No. P-4256); **3**. *Verruciretusispora pallida* (McGregor, 1960) Owens, 1971 (Sample No. B-4344); **4**. *Grandispora mammillata* Owens, 1971 (Sample No. B-4355); **5**. *Apiculiretosispora fructicosa* Higgs, 1975 (Sample No. B-4344); **6**. *Punctatisporites* sp. (Sample No. P-4267); **7**. *Retusotriletes rotundus* Streel, 1967 (Sample No. P-4267); **8**. *Cyclogranisporites isostictus* Balme, 1988 (Sample No. B-4351); **9**. *Cymbosporites* sp. A (Sample No. B-4351); **10**. *Geminospora antaxios* (Chibrikova) Owens, 1971 (Sample No. B-4351); **11**. *Cymbosporites* sp. B (Sample No. B-4351); **12**. *Cyclograndisporites* sp. (Sample No. P-4351); **13**. *Ancyrospora melvillensis* Owens, 1971 (Sample No. B-4351); **14**, **15**. *Geminospora lemurata* Balme, 1962 (Sample No. B-4334); **16**. *Retusotriletes pichovii* Naumova, 1953 (Sample No. P-4275); **17**. *Samarisporites concinnus* Owens, 1971 (Sample No. B-4351); **18**. *Raistrickia aratra* Hacquebard emend. Playford, 1964 (Sample No. B-4355); **19**. *Aurospora* sp. (Sample No. B-4355); **20**. *Samarisporites* sp. (Sample No. P-4267). Scale bars = 20 µm

and other taxa Famennian age for this part of the Bahram Formation is proposed (Fig. 5).

Four acritarch species have their first occurrence at the base of this biozone: *Cymatiosphaera primembrana*, *Gorgonisphaeridium descisum*, *Helospheridium microclavatum* and *Tornacea sarjeanti*. The new assemblage of acritarch species suggests the Famennian age for this part of the Bahram Formation (Ghavidel-Syooki et al., 2011) (See in Fig. 5).

MIOSPORE ASSEMBLAGE ZONE IV

This assemblage biozone occurrs in the Bahram Formation and extends through a thickness of 20 m consisting of fossiliferous limestone and

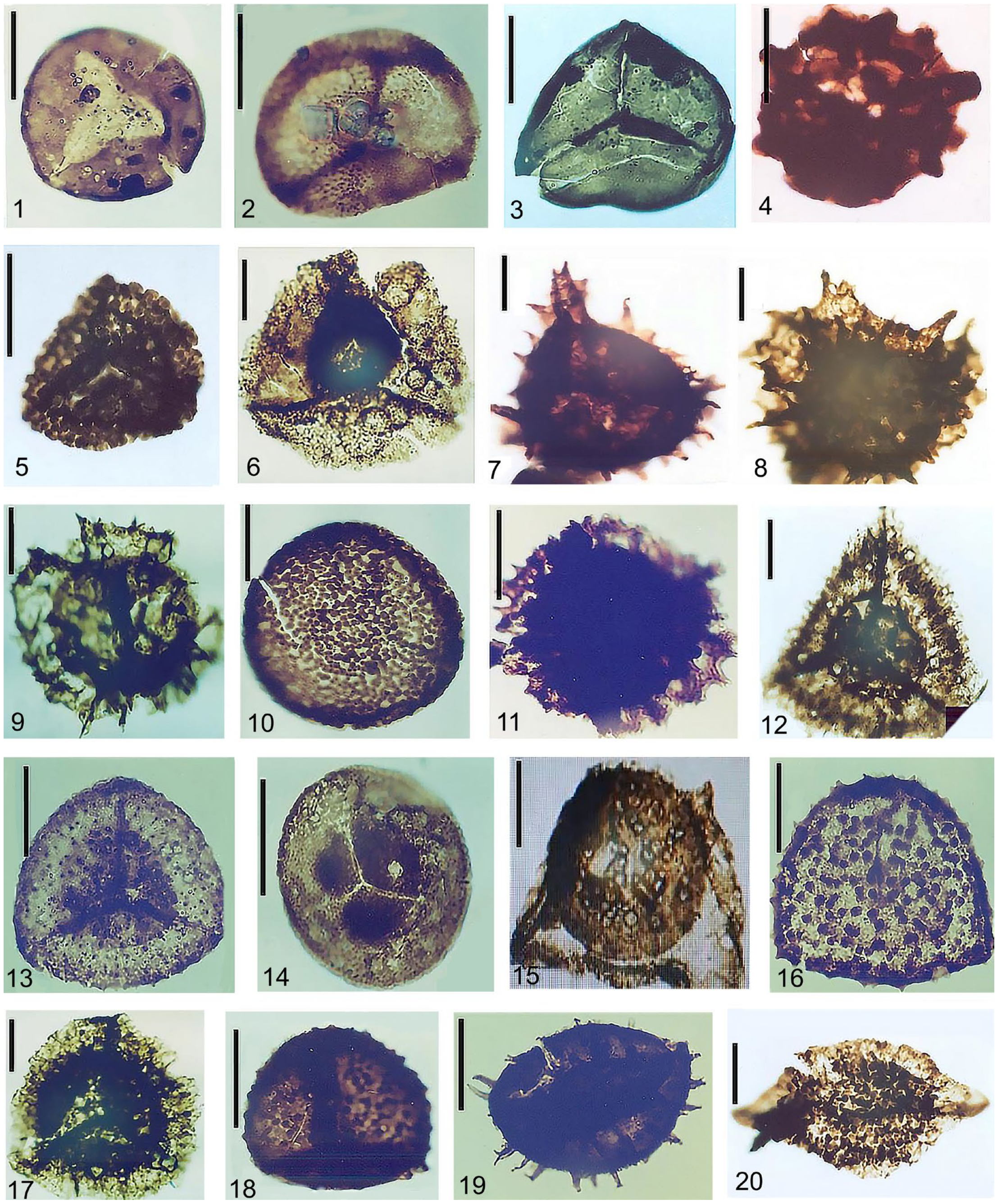

Plate 3. **1**. *Punctatisporites stabilis* Playford, 1962 (Sample No. B-4351); **2**. *Apiculiretusispora plicata* (Allen) Streel, 1987 (Sample No. P-4275); **3**. *Leiotriletes pagius* Allen, 1965 (Sample No. B-4351); **4**. *Verrucosisporites premnus* Richardson, 1965 (Sample No. B-4334); **5**. *Verrucosisporites* sp. (Sample No. B-4355); **6**. *Calyptosporites stolidotus* Balme, 1988 (Sample No. B-4351); **7**. *Ancyrospora furcula* Owens, 1971 (Sample No. B-4351); **8**. *A. ampulla* Owens, 1971 (Sample No. B-4334); **9**. *Ancyrospora* sp. (Sample No. B-4382); **10**. *Cymbosporites bormiscoides* Balme, 1988 (Sample No. B-4351); **11**. *Grandispora* sp. B. (Sample No. B-4351); **12**. *Vallatisporites pusillites* (Kedo) Dolby and Neves, 1970 (Sample No. B-4355); **13**. *Grandispora echinata* Hacquebard, 1957 (Sample No. B-4355); **14**. *Retusotriletes* sp. (Sample No. B-4355); **15**. *Teichertospora torquata* (Sample No. B-4355); **16**. *Retusotriletes pichovii* Naumova, 1953 (Sample No. P-4275); **17**. *Grandispora protea* Moreau-Benoit, 1980 (Sample No. B-4351); **18**. *Verrucosisporites confertus* Owens, 1971 (Sample No. B-4334); **19**. *Hystricosporites furcatus* Owens, 1971 (Sample No. B-4351); **20**. *Archaeoprisaccus opiparus* Owens, 1971 (Sample No. B-4351). Scale bars = 20 µm

shales (Fig. 5). Its lower boundary is identified by the first appearance of miospore species *Acinosporites macrospinosus*, *Ancyrospora furcula*, *Ancyrospora* sp., *Archaeoprisaccus opiparus*, *Calyptosporites stolidotus*, *Cyclograndisporites* sp., *Cymbosporites bormiscoides*, *Cymbosporites* sp. A, *Cymbosporites* sp. B, *Diducites plicabilis*, *Emphanisporites rotatus*, *Geminospora antaxios*, *Grandispora fibrilata*, *G. gracilis*, *Grandispora* sp. B, *Hystricosporites furcatus*, *Hymenozonotriletes perplexa*, *Hymenozonotriletes* sp., *Indotriradites explanatus*, *Leiotriletes pagius*, *Leiotriletes* sp., *Punctatisporites stabilis*, *Raistrickia aratra*, *Retusotriletes* sp., *Samarisporites*

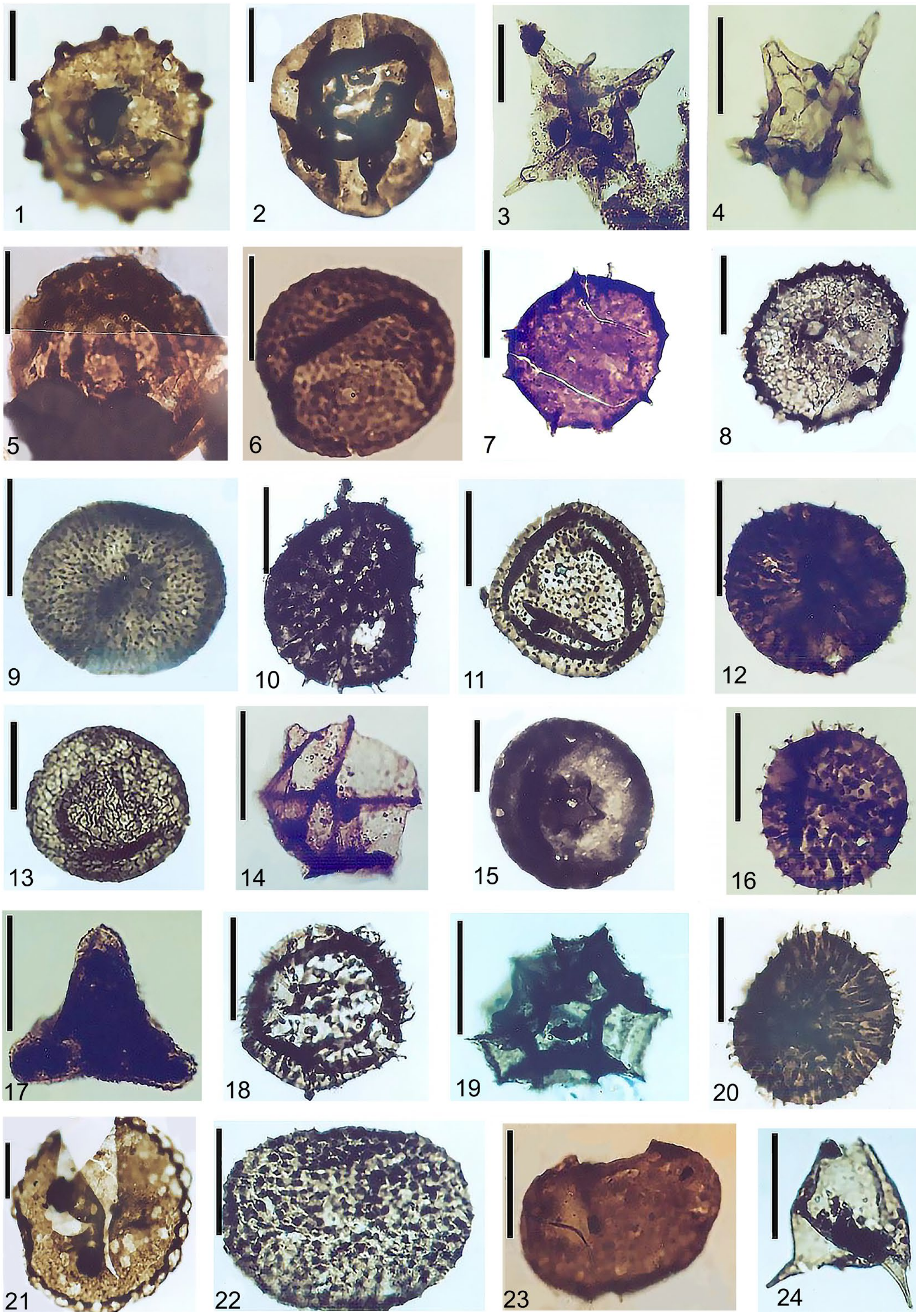

Plate 4. **1**. *Tornacia sarjeantii* Stockmans, Williere and Wicander, 1974 (Sample No. B-4334); **2**. *Leiosphaeridia* sp. (Sample No. B-4351); **3**, **4**. *Stellinium micropolygonale* (Stockmans and Williere) Playford, 1977 (Sample No. B-4334); **5**. *Chomotriletes vedugensis* Naumova, 1953 (Sample No. P-4262); **6**. *Lophosphaeridium deminutum* Playford and Dring, 1981 (Sample No. B-4342); **7**. *Michrystridium* sp. (Sample No. B-4351); **8**. *Maranhites perplexus* Wicander and Playford, 1985 (Sample No. B-4270); **9**. *Gorgonisphaeridium discissum* Playford, 1981 (Sample No. B-4334); **10**. *Umbellinasphaeridium* sp. (Sample No. B-4351); **11**. *Gorgonisphaeridium abstrusum* Playford and Dring, 1981 (Sample No. B-4344); **12**. *Gorgonisphaeridium plerispinosum* Wicander, 1974 (Sample No. B-4355); **13**. *Dictyotidium prolatum* Playford, 1981 (Sample No. B-4351); **14**. *Dictyotidium* sp. (Sample No. B-4351); **15**. *Papulogobata annulata* Playford and Dring, 1981 (Sample No. B-4316); **16**. *Gorgonisphaeridium condensum* Playford and Dring, 1981 (Sample No. P-4267); **17**. *Deltotosoma intonsun* Playford and Dring, 1981 (Sample No. B-4351); **18**. *Gorgonisphaeridium* sp. (Sample No. B-4355); **19**. *Cymatiosphaera perimembrana* Staplin, 1962 (Sample No. B-4355); **20**. *Helosphaeridium microclavatum* Playford, 1981 (Sample No. B-4355); **21**. *Maranhites* sp. (Sample No. B-4355); **22**. *Somphophragma miscellum* Playford and Dring, 1981 (Sample No. B-4355); **23**. *Navifusa exilis* Playford and Dring, 1981 (Sample No. P-4262); **24**. *Veryhachium downiei* Stockmans and Williere, 1960 (Sample No. B-4351). Scale bars = 20 μm

concinnus, *S. praetervisus* and *Vallatisporites pusillites* while its upper boundary is identified by the first occurrence of *Apiculiretosispora apsoga*, *Apiculiretusispora* sp., *Aurospora* sp., *Grandispora protea*, *G. mammilata*, *Stenozonotriletes* sp., *Tichertospora torquata* and *Verrocosisporites* sp. Some of these species are also present in the succeeding assemblage zone (Fig. 5). Based on the stratigraphic distribution of *Archaeoprisaccus opiparus*, *Indotriradites explanatus* and *Vallatisporites pusillites*, late Famennian age is proposed for this biozone (Fig. 5).

Additionally, acritarch taxa of *Dictyotidium prolatum*, *Dictyotidium* sp., *Deltotusoma intonsum*, *Gorgonisphaeridium plerispinosum, Micrhystridum* sp., *Somphophragma miscillum*, *Umbellinasphaeridium* sp. and *Veryhachium downiei* also support the late Famennian age for this part of the Bahram Formation (Ghavidel-Syooki et al., 2011) (see Fig. 5).

Most of the species of miospores and acritarch taxa disappear at the upper boundary of this biozone and only a few species are present in the overlying zone which suggests that the Devonian–Carboniferous boundary may be very close in the section, where a major acritarch extinction event occurred.

MIOSPORE ASSEMBLAGE ZONE V

The base of this biozone is marked by the first appearance of miospore species including *Apiculiretusispora apsoga*, *Apiculiretusispora* sp., *Aurospora* sp., *Grandispora mammilata*, *G. protea*, *Stenozonotriletes* sp., *Tichertospora torquata*, *Verrucosisporites* sp. while the upper boundary is marked by the last occurrence of *Ancyrospora* sp., *Cymbosporites* sp., *Grandispora echinata*, *Grandispora* sp., *Samarisporites* sp., *Verrucosisporites* sp., however, there is a significant reduction in the number of species (Fig. 5). On the basis of the stratigraphic distribution of *Grandispora echinata*, *G. mammilata*, *Apiculiretosispora apsoga*, *Tichertospora torquata*, late Famennian age is suggested for this biozone (Fig. 5).

DISCUSSION

Biostratigraphic studies of palynomorphs from Devonian strata have a long history worldwide. This chapter presents below a comprehensive biochronologic review of the most important index taxa of miospores and acritarchs of the Padeha and Bahram formations from the Shahzadeh Mohammad section. The species *Chomotriletes vedugensis* is pretty cosmopolitan in the Devonian, it has been recorded from the Frasnian sediments of Australia (Balme, 1962; Playford and Dring, 1981; Playford, 1981), Frasnian–Famennian sediments from South America (Argentina) (Ottone, 1996), North America (Wicander and Playford, 1985), Russian platform (Naumova, 1953) and from the Arabian plate (e.g. Saudi Arabia; Hemer and Nygreen, 1967). The species *Dictyotidium prolatum* and *Gorgonisphaeridium abstrusum* are Western Australian taxa, indicating the Frasnian age (Playford, 1981; Playford and Dring, 1981), while the species *Gorgonisphaeridium descissum* indicates the early Frasnian age in Western Australia (Playford, 1981; Playford and Dring, 1981). The species *Gorgonisphaeridium plerispinosum* is a quite typical taxon in Western Europe especially in the Famennian strata of Belgium (Vanguestain, 1978), while the species *Papulogabata annulata* indicates late Frasnian–early Famennian age in Belgium (Martin, 1985). *Lophosphaeridium deminutum* and *Somphophragma miscellum* reported from Western Australia indicate Frasnian age (Playford and Dring, 1981). *Stellinium micropolygonal* is an index taxon in Belgium and indicates Frasnian–early Famennian age (Stockman and Williere, 1966). *Navifusa exilis* is reported from the Frasnian strata of Western Australia (Playford and Dring, 1981) and from the Famennian of China (Lianda, 1986). The species *Tornacia sarjeantii* is a typical taxon of the Famennian–Tournaisian (early Carboniferous) strata of Belgium (Stockman and Williere, 1966) while the species *Veryhachium downiei* is typical in France in the early Carboniferous (Combaz and Streel, 1970). The species *Archaeoprisaccus opiparus* is common in the Upper Devonian formations of Canada (Owens, 1971). The *Ancyrospora ampulla* and *A. melvillensis* are typical miospores in the late Devonian of Canada (Owens, 1971). The species *Apiculiretusispora plicata* and *A. fructicosa* are typical taxa in the late Devonian–early Carboniferous of Britain (Turner et al., 1989). *Dibulisporites turiculatus* is an important taxon in Western Australia in the Frasnian strata (Balme, 1988) and *Geminospora lemurata* is quite typical in France in the Frasnian–Famennian layers (Loboziac and Streel, 1980). *Tichertospora torquata*, *Grandispora echinata* and *G. famenensis* are index taxa in Western Europe, indicating late Famennian age (Higgs et al., 2000; Streel et al., 1987). *Indotriradddites explanatus* is an important index taxon in North Africa (e.g. Algeria) and Western Europe (Portugal and Britain) and in North America, indicating late Famennian–early Tournaisian age (Clayton et al., 2002). The species *Vallatisporites pusilites* is a late Famennian–early Tournaisian index taxon in Ireland (Higgs, 1975). The species *Stenozonotriletes facilis* is a tropical taxon in Western Australia, indicating late Famennian–early Tournaisian age (Playford, 1976). Based on the typical species of miospores and acritarchs mentioned above, Padeha and Bahram Formations belong to Frasnian–Famennian age.

PALEOGEOGRAPHICAL INTERPRETATION

COMPARISON WITH OTHER LATE DEVONIAN MIOSPORE AND ACRITARCH ASSEMBLAGES

The palynomorphs recovered from the biozones I–V are closely comparable to those recorded from biozones associated with the Upper Devonian strata in Western Australia, North America (Canada and United States), Western Europe (France, Belgium), North Africa (Libya, Algeria), and in the Alborz, Zagros Mountains and the Central Iranian Range in Iran (Appendix 2). This similarity suggests that the notable palynomorphs were cosmopolitan and able to survive under similar climatic conditions. In addition, these similarities indicate that different parts of Iranian tectonic units formed a single land during the Paleozoic period that was part of the northern coastline of the Gondwana continent. Furthermore, the platforms of Iran, Western Australia and North Africa in the late Devonian (Frasnian–Famennian) show the same latitudes (Fig. 2).

PALAEOENVIRONMENTAL INTERPRETATION

According to the presence of the marine elements such as acritarch, scolecodonts and chitinozoans, although a large number of continental elements are also present (miospores), a shallow marine environment with

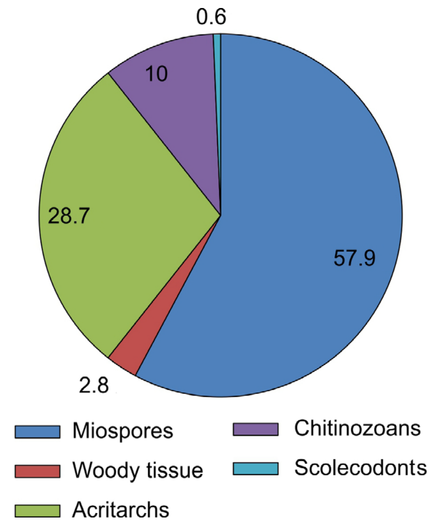

Figure 6. Distribution of palynomorph assemblage in the late Devonian section of Shahzadeh Mohammad area, NW Kerman

tropical conditions is suggested for the Shahzadeh Mohammad area during the late Devonian (Ghavidel-Syooki et al., 2011). This environment is also supported by the presence of marine microfauna (Tayefe Khabbazy, 2000). The ratio of the continental and marine elements is presented in Figure 6. Acritarchs play an important role in the reconstruction of the paleogeography. This group of microfossils has a small size, simple morphology (mostly spherical, psilate and possesses short processes) and a great variety, and is more abundant in terms of quantity and quality, and remains in better condition than other microfossils. Acritarchs have had a wide geographical distribution and were autotrophs. Most pre-Triassic acritarchs are thought to be marine organisms. In contrast, the miospores are produced by terrestrial plants and enter the sedimentary environment by transport (wind and water) as sediment particles. Destruction and debris settle along with the bodies of other sea creatures. Therefore, the higher number of spores in sediments than marine elements (Fig. 6 and Table 1) implies a sedimentary environment closer to the coastal

Table 1. The ratio of continental and marine elements of the Shahzadeh Mohammad area, NW Kerman

Counted elements			Relative Frequncy
Continental elements	Miospores	2596	57.9
	Woody tissue	127	2.8
Marine elements	Acritarchs	1276	28.7
	Chitinizoa	444	10
	Scolecodonts	29	0.6
Total		4472	100

environments. Acritarch assemblages in the samples of Padeha and Bahram Formations in association with terrestrial miospores indicate a shallow, near-shore marine environment. Due to the characteristics of acritarch assemblages, the variety and abundance of spores, the presence of *Archaeoperisaccus* implies a warm, shallow marine environment with a tropical climate. Based on the floral evidence, abundant miospore taxa occur in these two formations indicating a rich terrestrial plant community close to the coast (see Appendix 1).

CONCLUSION

Late Devonian miospores, acritarchs from the Padeha and Bahram Formations were studied herein. Based on the palynological research carried out in the Padeha and Bahram Formations, 57 species of 25 genera miospores and 23 species of 17 genera acritarchs have been identified. Stratigraphical distribution of miospores allows constructing five biozones, that are confirmed by the acritarch taxa occurrences. The studied stratigraphic section contains well-preserved palynomorphs. Biozone I is an interval zone distributed in the basement part of the Padeha Formation and an early Frasnian age has been proposed. Biozone II is an Assemblage zone, distributed in the upper part of the Padeha Formation and basal part of the Bahram Formation. This biozone belongs to the late Frasnian–early Famennian. Miospore biozone III is an assemblage zone that occurs in the Bahram Formation. This biozone has been proposed for the Famennian age. Miospore biozone IV is an assemblage zone that occurs in the Bahram Formation, and late Famennian age is suggested for this biozone. Miospore biozone V is an assemblage zone, located on the top of the Bahram Formation. Late Famennian age is suggested for this biozone. According to the palynomorph morphology evidence, a shallow marine environment with tropical conditions during the late Devonian is suggested for the Shahzadeh Mohammad area of Kerman. Furthermore, the occurrence of abundant miospore taxa in these two formations indicates that a rich terrestrial plant community existed along the coastline.

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Appendix 1. Quantitative distributions of miospore (**A**) and acritarch (**B**) taxa throughout the Upper Devonian (Padeha and Bahram Formations), Shahzadeh Mohammad area, northwest of Kerman, eastern-central Iran

Number	**A**. List of encountered miospores taxa	MG 4252	MG 4254	MG 4256	MG 4258	MG 4260	MG 4262	MG 4264	MG 4266	MG 4267	MG 4268	MG 4269	MG 4271	MG 4275	MG 4276	MG 4278	MG 4279	MG 4295	MG 4307	MG 4308	MG 4310	MG 4314	MG 4316	MG 4317	MG 4324	MG 4329	MG 4334	MG 4344	MG 4348	MG 4350	MG 4351	MG 4353	MG 4354	MG 4355	MG 4358	MG 4362	MG 4367	MG 4368	MG 4372	MG 4374	MG 4378	MG 4382	Total
1	*Samarisporites triangulatus*	2	.	.	.	.	.	6	.	3	.	.	.	3	.	.	.	.	.	.	.	.	3	.	.	.	9	3	.	.	200	.	.	36	.	.	.	.	.	.	.	.	265
2	*Dibolisporites turriculatus*	.	3	3	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	93	.	.	51	.	.	.	.	.	.	.	.	153
3	*Cyclogranisporites isostictus*	.	3	.	.	.	3	3	.	3	.	.	.	9	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	30	.	.	100	.	.	.	.	.	.	.	.	154
4	*Geminospora lemorata*	.	3	.	.	.	3	9	.	6	.	.	3	.	.	.	.	.	.	.	.	.	6	.	.	.	6	.	.	.	85	.	.	150	.	.	.	.	.	.	.	.	271
5	*Retusotriletes pychovii*	.	.	.	.	.	3	3	.	3	.	.	.	9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	12	.	.	.	.	.	.	.	.	36
6	*Leiotriletes* sp. A	.	.	.	.	.	15	21	.	45	.	.	36	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	3	.	.	.	.	.	.	.	.	126
7	*Apiculiretusispora fructicosa*	.	.	.	.	.	3	3	.	3	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	42	.	.	81	.	.	.	.	.	.	.	.	135
8	*Apiculiretusispora plicata*	.	.	.	.	.	3	3	.	3	.	.	3	3	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	3	.	.	.	.	.	.	.	.	24
9	*Retusotriletes distinctus*	.	.	.	.	.	30	41	.	.	3	.	.	.	12	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6	.	.	.	.	.	.	.	.	101
10	*Punctatisporites* sp.	.	.	.	.	.	3	3	.	.	3	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	3	.	.	.	.	.	.	.	.	21
11	*Calamospora punnucea*	.	.	.	.	.	3	6	.	.	3	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	12	.	.	6	.	.	.	.	.	.	.	.	39
12	*Retusotriletes rotundus*	.	.	.	.	.	6	6	.	.	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	3	.	.	6	.	.	.	.	.	.	.	.	36
13	*Verruciretusispora pallisa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	.	.	18	18	3	40	.	.	100	.	.	.	.	.	.	.	.	185
14	*Geminospora punctata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	12	.	.	33	.	.	.	.	.	.	.	3	57
15	*Grandispora echinata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	3	.	.	72	.	.	.	.	.	.	.	.	78
16	*Verrucosisporites premnus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	10	.	.	6	.	.	.	.	.	.	.	.	19
17	*Verrucosisporites confertus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	.	6	.	.	51	.	.	.	.	.	.	.	.	66
18	*Lophozonotriletes somphus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	9	.	.	9	.	.	.	.	.	.	.	.	21
19	*Grandispora fammenensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6	.	.	114	.	.	.	.	.	.	.	.	126
20	*Grandispora* sp. A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	3	.	.	9	.	.	.	.	.	.	.	.	24
21	*Ancyrospora ampula*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	6	.	.	12	.	.	.	.	.	.	.	.	21
22	*Hystricosporites furcatus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21	.	.	18	.	.	.	.	.	.	.	.	39
23	*Ancyrospora melvillensis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
24	*Ancyrospora furcula*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6	.	.	.	.	.	.	.	.	12
25	*Samarisporites praetervisus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	6	.	.	.	.	.	.	.	3	18
26	*Cymbosporites* sp. A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
27	*Cymbosporites* sp. B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6	.	.	.	.	.	.	.	.	12
28	*Hymenozonotriletes perplexa*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	12	.	.	.	.	.	.	.	.	24
29	*Geminospora antaxios*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	6	.	.	.	.	.	.	.	.	12
30	*Grandispora* sp. B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
31	*Raistrickia aratra*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	12	.	.	.	.	.	.	.	.	15
32	*Indotriradites explanatus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	12	.	.	.	.	.	.	.	.	15
33	*Raistrickia* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	2	.	.	.	.	.	.	.	.	4
34	*Grandispora gracilis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	6	.	.	.	.	.	.	.	.	9
35	*Acinosporites macrospinosus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	2
36	*Archaeoprisaccus opiparus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	3	.	.	.	.	.	.	.	.	9
37	*Calyptosporites stolidotus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	3	.	.	.	.	.	.	.	.	15
38	*Diducites plicabilis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	12	.	.	.	.	.	.	.	.	42
39	*Samarisporites concinnus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	30	.	.	.	.	.	.	.	.	33
40	*Vallatisporites pusillites*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	27	.	.	45	.	.	.	.	.	.	.	.	73
41	*Cymbosporites bormiscoides*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	9	.	.	.	.	.	.	.	.	21
42	*Cyclogranisporites* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	9	.	.	.	.	.	.	.	.	18
43	*Hymenozonotriletes* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
44	*Emphanisporites rotatus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
45	*Leiotriletes pagius*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
46	*Grandispora fibrilata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
47	*Punctatisporite stabilis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
48	*Ancyrospora* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
49	*Lieotriletes* sp. B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
50	*Grandispora protea*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
51	*Retusotriiletes* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
52	*Apiculiretusispirpora apsoga*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
53	*Grandispora mammilata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
54	*Teichertosporites torquata*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
55	*Aurospora* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
56	*Apiculiretusispora* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	3
57	*Verrucosisporites* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	51	.	.	.	.	.	.	.	.	51
Total		2	9	3	.	.	72	104	.	69	21	.	45	24	18	.	3	.	.	.	.	.	18	.	.	.	42	48	24	6	785	.	.	1145	.	.	.	.	.	.	.	6	2445

Appendix 1. Continued

Number	**B**. List of encountered acritarchs taxa	MG 4252	MG 4254	MG 4256	MG 4258	MG 4260	MG 4262	MG 4264	MG 4266	MG 4267	MG 4268	MG 4269	MG 4271	MG 4275	MG 4276	MG 4278	MG 4279	MG 4295	MG 4307	MG 4308	MG 4310	MG 4314	MG 4316	MG 4317	MG 4324	MG 4329	MG 4334	MG 4344	MG 4348	MG 4350	MG 4351	MG 4353	MG 4354	MG 4355	MG 4358	MG 4362	MG 4367	MG 4368	MG 4372	MG 4374	MG 4378	MG 4382	Total
1	*Gogonisphaeridium condensum*	.	2	3	9	.	3	6	.	3	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	6	3	6	.	.	178	.	.	150	.	.	.	.	.	.	.	10	385
2	*Gogonisphaeridium abstrusum*	.	3	6	.	.	12	24	.	6	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	6	.	9	.	.	81	.	.	111	.	.	.	.	.	.	.	15	276
3	*Leiosphaeridia* sp.	.	6	12	.	.	18	12	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	21	.	.	3	.	.	.	.	.	.	.	.	78
4	*Maranhites perplexus*	.	6	.	.	.	6	.	.	3	.	.	.	9	.	.	.	.	.	.	.	.	15	.	.	6	.	3	.	.	12	.	.	12	.	.	.	.	.	.	.	.	72
5	*Papulogobata annulata*	.	.	6	3	.	.	15	.	3	.	.	.	.	.	.	.	.	.	.	.	.	6	.	.	15	.	.	.	.	3	.	.	6	.	.	.	.	.	.	.	.	57
6	*Navifusa exilis*	.	.	20	6	.	6	9	.	60	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	9	.	.	3	.	.	.	.	.	.	.	.	116
7	*Lophosphaeridium deminutum*	.	.	.	.	.	6	12	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	.	.	6	3	3	.	.	9	.	.	90	.	.	.	.	.	.	.	3	141
8	*Chomotriletes vedugensis*	.	.	.	.	.	6	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9
9	*Stellinium micropolygonale*	.	.	.	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	6	.	.	.	.	.	.	.	.	16
10	*Gorgonisphaeridium* sp.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	3	.	.	9	.	.	.	.	.	.	.	.	18
11	*Dictyotidium prollatum*	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	8	.	.	.	.	.	.	.	.	17
12	*Gorgonisphaeridium descissum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
13	*Tornacia sargeantii*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	9
14	*Helosphaeridium microclavatum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	9
15	*Cymatiosphaera primembrana*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	27	.	.	30	.	.	.	.	.	.	.	.	60
16	*Gorgonisphaeridium plerispinosum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
17	*Maranhites* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
18	*Samphophragma miscellum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	.	.	.	.	.	.	.	.	6
19	*Dictyotididium* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	4	.	.	.	.	.	.	.	.	7
20	*Veryhachium downiei*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
21	*Deltotosoma intonsum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12	.	.	.	.	.	.	.	.	.	.	.	12
22	*Micrhystridium* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
23	*Umbellisphaeridium* sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	3
Total		.	17	47	18	.	67	81	.	81	.	.	6	12	.	.	.	.	.	.	.	.	36	.	.	51	6	24	.	.	391	.	.	450	.	.	.	.	.	.	.	28	1315

Appendix 2. Paleogeographic distributions of known miospore species in the area of Prince Mohammad Kerman with other parts of Iran and the world

Number species	Miospore taxa	Australia	North Africa	North America	Europe	Middle East	Alborz	Central Iran	Zagros
		Playford and Dring, 1981; Playford, 1981; McGregor, 1981	Coquel-Moreau and Benoit, 1986	Staplin, 1961; Wicander and Loeblich, 1977; Wicander and Wood, 1981	Downie, 1984; Rauscher, 1969, Cramer and Daiz, 1974; McGregor, 1961, 1981	Kimyai, 1972, 1997; Ghavidel-Syooki, 1988	Kimiyai, 1972, 1997, Coquel et al., 1977; Ghavidel-Syooki, 1992, 1994, 1995; Ghavidel-Syooki and Owens, 2007	Ghavidel-Syooki, 1994, 2001, Hashemi and Playford, 1998	Ghavidel-Syooki, 1986, 1988, 1994, 1996, 1999, 2003
1	*Apiculiretusispora fructicosa*	–	–	*	*	*	*	*	–
2	*Apiculiretusispora plicata*	–	–	–	*	*	–	–	*
3	*Apiculiretusispora apsoga*	–	–	–	*	*	*	–	–
4	*Apiculiretusispora* sp.	–	–	–	*	*	*	–	–
5	*Acinosporites macrospinosus*	–	–	–	*	*	*	–	–
6	*Ancyrospora ampula*	–	–	*	*	*	*	*	*
7	*Ancyrospora furcula*	–	–	–	*	*	–	–	*
8	*Ancyrospora melvillensis*	–	–	–	*	*	–	–	*
9	*Ancyrospora* sp.	–	–	*	*	*	*	*	*
10	*Archaeoperisuccus opiparus*	–	–	–	*	*	*	–	–
11	*Aurospora* sp.	*	–	*	*	*	*	*	–
12	*Calamospora pannucea*	*	*	*	*	*	*	*	*
13	*Calyptosporites stolidus*	*	–	–	–	*	*	–	–
14	*Cyclogranisporites isostictus*	*	–	–	–	*	*	*	–
15	*Cyclogranisporites* sp.	–	–	–	–	*	*	*	–
16	*Cymbosporites hormiscoides*	*	–	–	–	*	*	*	–
17	*Cymbosporites* sp. A	*	*	*	*	*	*	*	–
18	*Cymbosporites* sp. B	–	–	–	*	*	*	*	*
19	*Didusites plicabilis*	*	–	–	*	*	*	–	–
20	*Dibolisporites turriculatus*	*	*	*	*	*	*	*	*
21	*Emphanisporites rotundus*	*	*	*	*	*	*	*	*
22	*Geminospora lemurata*	*	*	–	*	*	*	*	*
23	*Geminospora punctata*	–	*	–	*	*	*	*	*
24	*Geminospora antoxios*	–	*	*	*	*	*	*	*
25	*Grandispora echinata*	–	–	–	*	*	*	*	–
26	*Grandispora famenensis*	–	–	–	*	*	*	–	–
27	*Grandispora protea*	*	–	–	–	*	*	*	–
28	*Grandispora fibrilata*	–	–	–	*	*	–	–	*
29	*Grandispora gracilis*	–	–	–	*	*	–	*	–
30	*Grandispora mammilata*	–	–	*	*	*	*	*	–
31	*Grandispora* sp. type	–	–	*	*	*	*	*	–
32	*Grandispora* sp. type B	–	–	–	*	*	*	*	–
33	*Hystricosporites furcatus*	*	–	–	*	*	–	*	–
34	*Hymenozonotriletes perplexa*	*	*	–	*	*	*	–	*
35	*Hymenozonotriletes* sp.	–	*	–	*	*	*	*	*
36	*Indotriradites explanatus*	–	*	–	*	*	*	*	*
37	*Leiotriletes pagius*	*	–	*	*	*	*	*	*
38	*Leiotriletes* sp. A	*	*	*	*	*	*	–	–
39	*Leiotriletes* sp.	–	*	–	*	*	*	*	*
40	*Punctatispotites stabilis*	*	–	*	–	*	*	*	*
41	*Punctatispotites* sp.	*	–	*	*	*	*	*	*
42	*Retusotriletes distinctus*	*	*	–	*	*	*	*	*
43	*Retusotriletes pychovii*	*	–	*	*	*	*	*	*
44	*Retusotriletes rotundus*	–	*	*	*	*	*	*	*
45	*Retusotriletes* sp.	–		–	*	–	*	–	–
46	*Raistrickia aratra*	*	*	*	*	*	*	–	–
47	*Samarisporites triangulatus*	–	*	–	*	*	*	–	–
48	*Samarisporites praetervisus*	–	*	–	*	*	*	*	*
49	*Samarisporites consinus*	*	–	–	*	*	–	–	*
50	*Samarisporites* sp.	*	–	*	–	*	*	*	*
51	*Tichertospora torquata*	*	*	*	*	*	*	*	*
52	*Vallatisporites pusillites*	*	–	*	–	*	*	–	–
53	*Verruciretusispora pallida*	–	*	*	–	*	*	–	–
54	*Verrucosisporites confertus*	–	–	*	*	*	*	*	–
55	*Verrucosisporites permnus*	–	–	*	*	*	*	*	–
56	*Verrucosisporite confertus*	–	–	*	*	*	*	*	*
57	*Verrucosisporites* sp.	–	–	*	*	*	–	*	*